1 Context of the fleet test

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This chapter will give a short introduction to the context of the fleet test. The following chapters will then provide detailed information on the research conducted during the time of the fleet test. As each chapter solely provides information about the individual treated topic this chapter will rather highlight the environment in which these researches had been performed. This will help the reader to understand certain singularities which had to be faced during the fleet test.

In section 1.1 the involved partners and their tasks will be described briefly. In the following section we explicate the concept and the challenges of interoperability during the fleet test. Section four gives a rough overview on the fleet schedule and section 1.4 gives an overview of all employed EV. Finally the charging infrastructure of the fleet is presented.

1.1 Partners in the fleet test and their main activities

Different French and German industry partners and research organisations participated and introduced their knowledge into the fleet test. They were supported by several associated partners, mainly French and German regional institutions. The project was funded by French and German Ministries: On French side the Ministry for Ecology, Sustainable Development and Energy (Ministère de l'Ecologie, du Développement Durable et de l’Energie), the Ministry of Industry (Ministère du Redressement Productif) and the Ministry of Academic Education and Research (Ministère de l’Enseignement Supérieur et de la Recherche), on the German side the Federal Ministry for Economic Affairs and Energy (Bundesministerium für

Wirtschaft und Energie) and the Federal Ministry of Transport and digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur).

In the following a short description of the main tasks of the full partners is given. We are focusing here only on the tasks related to the fleet test and do not mention all other tasks undertaken by the partners. Furthermore, we make no claim to be complete here.

The **original equipment manufacturers (OEM)** Daimler AG, Dr. Ing. h.c. F. Porsche AG, PSA Peugeot Citroën SA and Renault SA provided the EV which were employed in the project. Their specifications are described in section five. Daimler developed a conformance test tool for Mode 3 charging processes (ISO 15118), accompanied the cross-border infrastructure standardisation process and also brought two types of EV into the project. A total of 60 cars split between the models smart fortwo electric drive and Mercedes-Benz A-Klasse E-CELL were involved in the project. Hereby, the company could gain some important insight on market research and customer acceptance. Within the fleet test Porsche focused on the installation and the actual testing of battery-operated electric sports cars without combustion engine in form of the Porsche Boxster e model as well as the testing of vehicles from the Panamera family with plug-in technologies and their use in cross-border mobility. The brands Peugeot and Citroën participated in the fleet test with approximately 35 mass produced EV: About 30 Peugeot iOn and Citroën C-ZERO as well as some Peugeot Partner Origin and Citroën Berlingo were brought into the fleet test and used in normal conditions by private and commercial clients. In cooperation with the research institute IFSTTAR ten Peugeot iOn and Citroën C-ZERO were equipped with additional data loggers. Renault brought seven mass-produced Kangoo Z.E. into the fleet.

For all OEMs the main findings were primarily derived from the challenge of a cross-border use of EV, as e.g. the different mode of operation of charging stations and several billing and payment systems as well as different plug types. The different additionally aspects that were put under test included the batteries' durability, charging and discharging cycles, the users' acceptance EV as well as the safety in traffic under everyday conditions.

The **utilities** Électricité de France SA (EDF) and Energie Baden-Württemberg AG (EnBW) provided and developed several EV specific services (cf. chapter 5) as well as comprehensive interoperable electric vehicle supply equipment (EVSE) infrastructure (cf. section 1.5). EDF focused within the fleet test on (1) user acceptance analysis based on experiences during former projects (e.g. Kléber in Strasbourg), (2) designing and defining studies on the interoperable charging infrastructures and roaming platform as well as (3) supporting the local territories (Communauté urbaine de Strasbourg, region Moselle, Thionville, Forbach, Sarreguemines, and Colmar) in order to deploy public charging stations (e.g. upstream specifications). For the latter task European conform calls for tenders for interoperable EVSE were developed, which were used as a blueprint in many other regions during the last years. Additionally, together with NISSAN and CORA CHAdeMO fast charging EVSE where installed and operated. EnBW took over the corresponding role on the German side and installed and are operating an interoperable charging infrastructure in Baden along the French-German border in cooperation with local energy suppliers as well as the development of innovative tariff and access concepts for public EVSE. Whereas in Germany the rollout of the EVSE was supported by EnBW, in France the rollout was financed by the local authorities (which seems to be closer to real market conditions). For the rollout EnBW made use of the experiences from the MeRegioMobil project in Karlsruhe and Stuttgart. Together with other partners EDF and EnBW contributed substantially to the development and implementation of the interoperable electromobility platform.

The **electric infrastructure and service oriented industrial partners** such as Schneider Electric SA, Siemens AG and Bosch Software Innovations GmbH installed further infrastructure and developed a comprehensive roaming layer, which was used to provide service interoperability in the fleet test. This infrastructure represents a cornerstone of current European roaming for EV by inertercharge (cf. chapter 5). Bosch Software Innovations provided and operated special internet services for electromobility. These services allowed the necessary communication among all parties involved in the fleet test to offer an interoperable charging for the customers. Furthermore, other added value services such as navigation and networked fleet management were discussed with all partners and partly implemented. The Siemens AG supported the project partners in the topic of interoperability of the alternating current (AC) charging infrastructure (Mode 3), security aspects during the charging process and the installation and testing of direct current (DC) charging stations (Mode 4, CHAdeMO). Additionally, Siemens integrated infrastructure in the developed roaming layer and tested existing standards on plugs and charging protocols between the EV and the EVSE (mainly ISO15118) as well as between EVSE and the backend (e.g. OCPP). Schneider Electric SA performed different tasks within the fleet test (e.g. requirements for interoperable charging stations deployed in France), providing Mode 3 charging solutions, contributing to the standardization process on charging interfaces as well as designing and developing advanced energy management systems for EVSE.

The core task of the Institut français des sciences et technologies des transports, de l'aménagement et des réseaux (IFSTTAR) was to analyse vehicle data from the french EV. The Karlsruhe Institute of Technology (KIT) and the European Institute for Energy Research (EIFER) carried out **accompanying research analyses** during the whole project duration. The research performed by these institutes cover most scientific aspects within the fleet test and is described in detail in this book.

Associated partners are mainly regional partners on both sides of the border. On the French side these are regional corporations:

- Conseil Général de la Moselle,
- Communauté Urbaine de Strasbourg,
- Région Alsace,

on the German side the regional energy suppliers:

- E-Werk Mittelbaden,
- Stadtwerke Karlsruhe,
- Stadtwerke Baden-Baden and
- Star.Energiewerk Rastatt.

Further partners are:

- Verband der Automobilindustrie (VDA) and
- EIFER.

1.2 Interoperability

Interoperability was identified as a key aspect within the bi-national fleet test. In the beginning of the fleet test three main domains were identified in which certain interoperability had to be established in order to allow cross border mobility for EV: (i) hardware (in particular for EV charging), (ii) software and services as well as (iii) billing (for charging and service usage). While these domains usually require analysis in the field of systems engineering and information technology to allow the necessary information exchange we integrated organisational, political, and social perspectives, too. In doing so, a coherent infrastructure of technically differing solutions and services for the individual components in the fleet test were developed and implemented.The objective was to provide and test a first interoperable system of several dozen EVSE in two countries which may serve as a cornerstone for a barrier-free Europe-wide interoperable system, which allows charging an EV wherever needed.

Therefore, the following two foci (minimum requirements) were prioritized in the fleet test: each EV can technically connect to all EVSE within the system (i.e. compliant socket system) and each EV user can authenticate oneself at each EVSE (e.g. via Radio-Frequency Identification (RFID) card).

At the beginning of the fleet test in 2011, the **hardware interoperability** was not given. On the French side most charging stations (mainly operated during the Kléber project) were equipped with a domestic socket (Mode 2) and for Mode 3 with the Italian-French socket type (Type 3 plug system). Furthermore, several charging stations provided a "camping socket" outlet (Blue P+N+E-Socket according IEC 60309) for the first TOYOTA Prius plug-in hybrid electric vehicle (PHEV) version. On the German side the MeRegioMobil based charging stations are equipped with domestic sockets and Type 2 (i.e. "Mennekes") outlets. Hence, only an interoperable Mode 2 charging was possible and not the preferred Mode 3 charging.

Therefore, in the fleet test, the following steps had been performed: At least (additionally to the already existing infrastructure) 25 charging stations have been installed in public areas on each side of the border. Besides domestic socket outlets, these charging stations were each equipped with both, Type 2 and Type 3 socket outlets ("dual type socket" charging) and allowed for up to 22 kW charging. It was intended to retrofit these dual socket spots later in order to comply with the European standardisation decision[1]. This was taken in 2013 and favours the Type 2 socket system.

In 2011 the situation of **Software, service and billing interoperability** has been even worse. Most of the charging processes were free of charge and authentication technologies – if necessary – were very diverse. Only the already installed EVSE by EnBW provided a unique billing system.

For improving this situation a new and broadly accepted concept has to be developed. This concept should consider requirements of all European stakeholders (i.e. EVSE as well as EV providers and operators, utilities, etc.) as well as EV users. Also future developments in specific services in all relevant fields (e.g. navigation, EVSE reservation, further authentication) should be taken into account. To assure interoperability for software and services the following steps have been established during the fleet test: (1) unified access and authentication concepts based on proofed systems like

[1] Directive COM(2013)0018

RFID, NFC, (2) cross border billing and roaming concepts based on different payment methods, (3) interoperable smart charging concepts (based on IEC 15118), (4) management concepts to control and monitor the charging infrastructure as well as (5) unified connectors for data exchange between the partners are analysed developed and implemented. Basis for this concept was a unified roaming service layer (cf. Figure 2) which also served as basis for several implemented smart functionalities e.g. route optimizing and charging spot reservation.

Figure 1: Dual Charging Station for Type 1 and 2 in France.

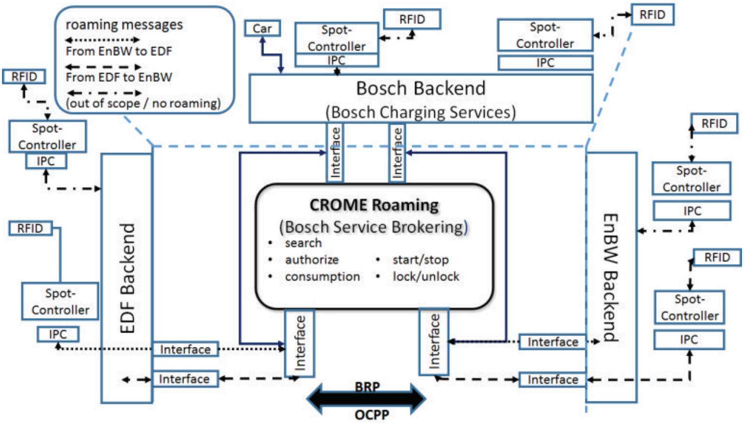

Figure 2: The roaming layer architecture by Bosch used in CROME in order to allow interoperable charging and other services.

1.3 Timeline

From January 2011 to December 2014 the following steps have been performed during the fleet test:

In the beginning of 2011 the EV prototypes were set up, commercial conditions fixed and possible users identified[2]. Afterwards the roll out of the EV started and their usage was monitored until the end of 2013.

In the beginning of 2011 first the technical specifications for the EVSE had to be validated in order to subsequently install and operate the dual type EVSE within the fleet test region. In the beginning of 2012 EVSE with DC-fast-charging capabilities for EV (Mode 4, CHAdeMO) were installed and operated[3]. Additionally, German OEM tested DC charging (Mode 4) with CCS-System with their company cars in 2013.

[2] The users were neither chosen nor subsidized. This resulted in a user characteristic which is specified in chapters 8 and 10.

[3] This infrastructure has also been used for the Alsace Corridor Energétique and the project RheinMobil.

Regarding services from 2011 to 2012 multiple tasks concerning the communication of EVSE and EV, the unified access and authentication system as well as the development of the roaming service layer were performed. In 2013 further advanced services and the connection of the EVSE to the backend system were implemented and operated.

A billing system between the German EVSE operators in the fleet test was established in 2012. In 2013 additionally French EVSE operators were included into the billing system.

The conducted accompanying research exemplified in detail in the following chapters started with preliminary tasks in 2011 and continued until 2014 when a final deep analysis of the data from the fleet test has been conducted.

1.4 EV in the fleet test

The target number of cars to be brought into the fleet test was set to a minimum of 100 of which most were battery electric vehicles (BEV) and only few PHEV. The fleet included vehicles ranging from small cars to sports cars and utility vehicles. These were either series vehicles which are and were offered for sale to final customers or small series vehicles which could be leased by the customers (see chapter seven and eight for a detailed discussion on the customers). Within the fleet test even some prototypes were tested by Porsche. Most EV were able to charge in Mode 2 (domestic sockets) and in Mode 3 (with Type 2 or Type 3 cables) (cf. Table 1). Only few vehicles additionally supported DC fast charging up to 43 kW.

1.5 Installed infrastructure

A key objective of the fleet test was to demonstrate solutions which allow users to connect their EV to EVSE throughout Europe.Therefore, in a first step these solutions had to take into account the infrastructure which had already been deployed in France and Germany in 2011. In the beginning of the field test each user had to carry three cords for assuring interoperability (i.e. Mode 2 with domestic plug as well as two Mode 3 cables, one with a Type 3 and the other one with a Type 2 plug). The idea of providing each user with three different cords was abandoned as it would neither support a sustainable interoperability on charging spots nor meet the customer needs. The dual type socket solution has been introduced instead (see above) and all already operated EVSE by project partners have been altered correspondingly. They allow for Mode 2 charging and Mode 3 charging up to 22 kW. At the end of the fleet test 50 EVSE equipped with dual type sockets granted a minimum of interoperability testing the project region (cf. Figure 3).

Each EV has been delivered to the fleet test with a set of two cords: one for Mode 2 charging (domestic plug) and the other for Mode 3 charging (in Germany Type 2 plug and in France Type 3 plug).

Figure 3: Geographical venue of the fleet test.

Table 1: Characteristics of applied EV in the fleet test.

Max. speed (km/h)	Range (km)	Plug type (EV side)	Charging mode	Battery energy (kWh)	Commercial launch	Production	Category	
150	255	2	2/3	36	2010	Series	BEV	**Mercedes Benz A-Klasse E-CELL**
130	150	1	2/3/4	16,3	2010	Mass	BEV	**Peugeot iOn / Citroën C-ZERO**
110	120	2	2/3/4	23,5	2010	Mass	BEV	**Peugeot Partner Origin / Citroën Berlingo First**
150/200	170	2	2/3	26	-	Prototype	BEV	**Porsche Boxster e**
130	170	2	2/3	22	2011	Mass	BEV	**Renault Kangoo Z. E.**
100	135	2	2/3	16,5	2009	Series	BEV	**smart fortwo electric drive**
180	25	1	2/3	4,4	2012	Series	PHEV	**Toyota Prius**
270	30	2	2/3	7,5	-	Prototype	PHEV	**Porsche Panamera S Hybrid**

1.6 The project's major learnings

Europe-wide standards for the further development of electromobility are crucial

The project has demonstrated that interoperability is feasible based on the existing technologies on both sides of the border: The fleet test showed that both the type 2 and type 3 plugs and sockets can be implemented in one charging station according to the regulatory constraints on each side of the border in a way that easy retrofitting is ensured. Both types enabled charging of the EV in the project. Although technically feasible, this solution does not appear meaningful on the long term. In order to reduce the costs for the deployment of the infrastructure, complexity of hardware, and to increase the user acceptance, the CROME partners recommended an agreement at European level on one standard type of plug and the deployment of charging stations which can be easily retrofitted if decided by the infrastructure owner, so that the costs for the adaptation to a future standard remain as low as possible. Thanks to the development of common specifications for mode 3 compliant public charging stations and to the preparation of the corresponding initial call for tender together with CUS, CROME contributed to simplify the erection of mode 3 charging stations in France. The CROME terms of reference for the charging infrastructure have already been adopted by further border regions in France, e.g. Pas-de-Calais.

Fast charging is used and meets EV customer needs

The CROME project demonstrated that electromobility corridors are an appropriate pattern in order to interlink already “electrified regions”. However, interoperable and multi-standard *fast charging facilities* are required in order to cope with the different EV types on the market and foster the exchange between the regions. The CROME project proved that CCS charging and high level communication according to ISO / IEC 15118 work properly.

CROME demonstrated service interoperability by roaming of services

The detailed definition added to the mode 3 specifications enabled a reliable cross-border charging. In this respect, no further developments are needed. The adoption of the CROME terms of reference for charging in mode 3 has contributed to the development of an industrial offer in terms of infrastructure.

The RFID card is a suitable media for ensuring roaming; within the project, the technology has proved to be user-friendly and reliable. In addition, a live retrieval of the information needed between the backends avoids keeping data in all the systems. Consequently, e. g. in case a RFID-card gets lost, it is sufficient to disable it in one of the systems to have it immediately disabled in all the network of connected systems.

The Open Charge Point Protocol (OCPP) allows a flexible connection of different charging stations to a backend system. It brings the advantage of being a de facto standard used by different providers. However, a connection requires the relevant partners to agree upon a common communication layer.

It was demonstrated that the selected roaming architecture works and is accepted by all the partners connected, as it supports current as well as future business models. The CROME partners recommend for a future marketplace to build a network of independent international partners (competitors) having their autonomous business and systems, the system design ensuring that each partner keeps his independence (data). It was proven, that real-time authorization between the partner systems linked via a roaming layer can be realized without any noticeable delay compared to the authorization within one partner system. This allows respecting the principle of minimized data storage and avoids large scale whitelist solutions.

Linking vehicle data to backend systems makes innovative services possible; however, specific legal framework conditions are to be considered. The roaming of services will be a key enabler for future mobility solutions.

Cross-border billing needs a clear legal framework

A clear legal framework is necessary for the implementation of cross-border billing, especially with respect to the billing of the value-added tax. Furthermore, showing a customized pricing table at the charging station of each provider may considerably increase the cost transparency for the end user. Similarly, transferring the pricing table via roaming service layer in connection with the authentication service also seems to make sense.